

Hazards of Surgical Diathermy

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Abstract

Background: Surgical diathermy is an invaluable facility widely used in the operating theatre. Its application in surgical practice is rapidly expanding. However, its use may be accompanied with hazards, which this review is intended to highlight.

Method:s Publications from local and international journals were reviewed.

Results: The role of diathermy in surgical practice has expanded beyond imagination in recent years. The patient, surgeon and the theatre staff are frequently exposed to hazards such as burns injury, electrocution, hypoxic stress, inhalation of diathermy plume, and gene mutation. However, strict adherence to preventive measures such as proper connection and handling of diathermy machine, avoidance of inflammable theatre gases, the use of suction device, theatre scavenging system and diathermy plume extraction system could significantly reduce the hazards.

Conclusion: Continuous exposure to electrocautery appliances in surgical practice is associated with potential risks. Optimizing health and safety in work place should be an ongoing goal. Hence, all methods geared toward the reduction of these risks to health should be emphasized.

KEYWORDS: Diathermy, surgery, hazards

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INTRODUCTION

The use of heat for therapy in surgical practice can be traced back to 300B C when Egyptians used it for the treatment of tumours.¹ The use of diathermy in modern surgery was first introduced by Czerny in 1910 when he described electro dissection or cutting by means of an electric current.^{1,2} Since then diathermy has remained one of the invaluable facilities widely used in the operating theatre.^{3,4} Its application in surgical practice is rapidly expanding, though not without possible hazards to the patient, surgeon and the operating team.^{5,6} The aim of this review is to highlight the hazards of surgical diathermy and raise awareness among members of the surgical team and operating theatre staff. Preventive measures are also discussed.

OPERATING PRINCIPLES OF SURGICAL DIATHERMY

Surgical diathermy utilizes high frequency (300KHZ-3MHZ) alternating current to generate sufficient heat in the tissues, which effect cellular changes.^{1,3,4} The heat produced depends on the intensity of the current, wave form, the electrical property of the tissue through which the current passes and relative sizes of the two electrodes.^{3,4}

Different surgical diathermy machines exist and are in use in surgical practice, ranging from those operating on the spark gap principle (fig. 1) producing energy at a frequency of about 400KHZ which achieves coagulation but poor cutting^{2,3,4} to a more recent model (fig 2) which uses valve oscillators producing energy at a frequency of 1.6-3MHZ which produces cutting but poor coagulation.

Fig 1: Old diathermy machine that uses spark gap principle



Fig 2 Recent model of diathermy machine that uses valve oscillators

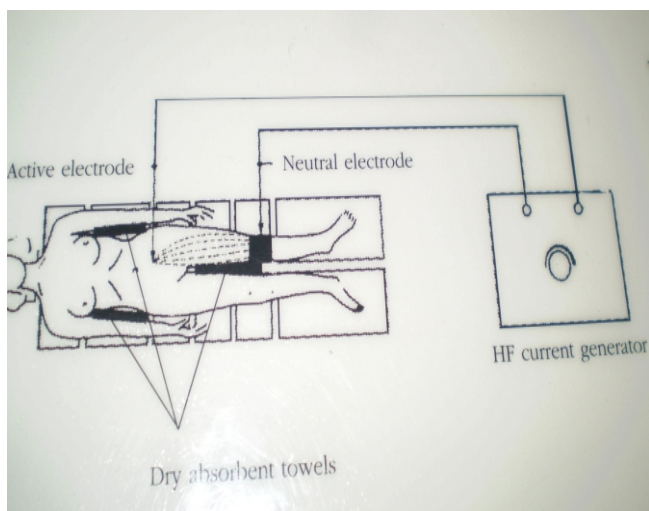


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The active electrode is always small compared to the indifferent (neutral) electrode and could be in the form of a needle, a blade, a button, or a pair of forceps. Consequently, there is concentration of heat beneath the active electrode often sufficient to coagulate (coalesce blood proteins, drying and shrinkage of cells in the vessel wall and retraction of the vessel), fulgurate and/ or form an arc between the tissue and the electrode.

Whichever type of machine is being used, the basic principle at the cellular level remains the same. The current is produced by the diathermy generator and passes through the active electrode to the patient and via the large indifferent electrode (unipolar) back to the earthed pole of the generator (fig 3). Electrical energy is usually converted to heat energy at both electrodes. However, since the indifferent (neutral) electrode is relatively large (approximately 300cm²), the heat is reduced to a minimum and is dissipated rapidly. The heating effect beneath the active electrode liberates by-products such as carbon monoxide and complex hydrocarbons contained in the aerosol which the operating staff or team is liable to inhale.⁷ Therefore, the operating team is exposed to many risks of developing different symptoms resulting from repeated use and exposure to diathermy plume (smoke).

Fig 3. Complete circuit.



PATHOPHYSIOLOGIC EFFECTS ON TISSUES

The heat generated in tissues during the use of diathermy burns the tissue, proteins and lipids and evaporates fluid and electrolytes.^{5, 7} Hence, excessive formation of necrotic tissue may result especially following over zealous use of diathermy. The surgical smoke produced contains chemicals^{7, 8} and particles that when inhaled repeatedly can cause symptoms such as airway

inflammation, eye irritation, hypoxic stress and dermatitis.⁷⁻⁹ More recently, accumulated evidence has shown that the aerosol from electrocautery smoke might carry viable cells, tumour cells and virus particles.⁷

HAZARDS

The use of surgical diathermy poses some danger to the patient on the one hand and the surgeon and the entire operating team on the other.^{3, 5, 10} It is important that surgeons and operating theatre staff are not only familiar with the hazards they are often exposed to daily in handling and using diathermy appliances, but should also ensure and create a conscious effort at averting these hazards. These hazards include;

Burn injury: The patient is at risk of sustaining three type of burn injury.

- (a) Diathermy (thermoelectric) burns -this may occur in several ways;¹¹ application of diathermy too close to the skin,¹¹⁻¹³ the return of earthed current to stray contact points on the operating table¹², inadequate application of the plate (indifferent) electrode so that it makes too small an area of contact,^{13,14} break in the cable connecting the indifferent electrode to the machine such that the current is earthed through the body; burns could occur at any of these points of contact.^{14 15} Most importantly, an inadvertent activation of the circuit while doing other things so that the active electrode possibly resting near the patient's skin^{15,16} could cause burns.
- (b) Burns on the skin or cavities (e.g. umbilicus, vagina) may occur from the use of inflammable antiseptic solutions such as alcohol^{5,6,12} especially if diathermy is used before the antiseptic dries out.
- (c) Burn injury can also be sustained by the surgeon or any member of the operating team⁵ as a result of not only wrong handling of the appliances¹⁷ but also from the steam and hot particulate matter generated in the field of surgery.¹⁸

Table 1 Sources of burns injury when using diathermy

1. Diathermy burns
Application of diathermy too close to skin
Return of current earth to stray contact point
Inadequate application of plate electrode
Break in the cable connecting indifferent electrode
Inadvertent activation of the active electrode

2. Inflammable antiseptic solutions (e.g. alcohol)

Skin
Umbilical cavity
Vagina

3. From the field of surgery

Steam
Hot particulates

Explosion: This could occur commonly from two sources (though it is a remote risk now that highly flammable gases are rarely used in open circuits);

- (a) During use of flammable volatile anaesthetic gases¹⁷ such as ether (in exceptional cases where ether is the anaesthetist's choice), and cyclopropane.
- (b) In surgery involving hollow gastrointestinal viscera, if mannitol is used for bowel preparation or when there is intestinal obstruction; production of hydrogen (H₂) and methane from metabolism of carbohydrate in the diet and bacterial action respectively^{5, 18, 19} can occur and the accumulated gases may reach sufficient explosive concentrations.

Channeling effect: If the organ to which diathermy is being applied has attachment or pedicle to the body narrower than the diameter of the organ concerned, then the passage of the current through a pedunculated part will concentrate its intensity so that coagulation at the narrowest point may occur⁵ (fig; 4). The current will pass with greatest intensity where there is the highest concentration of electrolytic solution and this can very well be the blood vessel supplying the organ which may go into spasm and thrombose, resulting in ischaemia.^{20, 21} This commonly occurs, if unipolar diathermy is used during procedures on organs such as penis, digits and testis.^{20, 21} Several disasters have occurred from the use of diathermy in circumcision.¹⁹⁻²¹

Fig 4: channeling effect



Wound infection and poor wound healing:

Excessive use of diathermy may lead to the formation of excessive necrotic tissue which will subsequently act as a good culture medium for the proliferation of bacteria. Also, many vessels coagulated during this procedure have been shown to cause extensive tissue ischaemia, so much so that wound healing may be delayed. This may occasionally lead to wound dehiscence.⁵

Secondary haemorrhage: Patients are at risk of developing secondary haemorrhage when the necrosed vessel wall sloughs off later.³ The bleeding may be torrential enough to threaten the patient's life, especially if moderate to large vessels are involved.

Perforation of hollow viscera: The use of diathermy in hollow viscera as in endoscopic surgery is expanding rapidly.^{3, 5, 6, 23} Diathermy is commonly used to fulgurate intraluminal and pedunculated growths in hollow viscera.²³ During this procedure, it may be difficult to control the depth of the tissue necrosis. Hence, the risk of extensive tissue necrosis with perforation of hollow viscera may be high.

Electrocution: This is another common hazard that patients, surgeon and other members of the operating team are exposed to. It is usually due to faulty connections accompanied with electric current leak.^{5, 6, 14, 24}

Arrhythmias: The risk of developing arrhythmia is important especially in patients with cardiac pacemakers⁵. The pacemaker may be damaged; imbalance of the electrolytes in the myocardium may alter its electrical activities thereby resulting in ventricular fibrillation and other forms of arrhythmias.^{5, 17}

EFFECTS OF DIATHERMY SMOKE

Irritation to the Eyes: Electrocautery smoke has been found to contain significant amount of chemical that constitute irritants to the eye^{7, 8} therefore the eyes of the surgeon, patient and other members of the operating team are at the risk of developing eye symptoms such as conjunctivitis and excessive tearing.⁷

Acute airway inflammation: surgical smoke contains hazardous chemical⁷ exposure to it and inhalation may cause symptoms such as coughing, difficulty breathing and fever.

Hypoxic stress: The burning of protein and lipids during electro surgery liberates by-products, which

cause acute inflammation of the airways. The carbon monoxide contained in the aerosol may cause hypoxic stress in healthy patients and operating team owing to its high affinity for haemoglobin. Reduced oxygen-carrying capacity of the blood may impair cardiovascular function in patients with pre-existing cardiovascular disease⁶ and haemoglobinopathies.

Transmission of infection: Transmission of viruses and other infectious agents from patient to surgeon or vice versa have remained one of the topical issues and major concern in surgical practice. In addition to the known mutagenic agents contained within electrocautery smoke, infectious agents such as prions may be present^{3, 25, 26, 27, 28} and the concern regarding the presence of these viable virus particles and infectious agent^{27, 28} has continued to increase as this can be transmitted from patient to any member of the operating team when inhaled.²⁸ Studies have shown a higher incidence of nasopharyngeal lesions in carbon dioxide laser surgery and that human immunodeficiency virus (HIV) in carbon dioxide laser smoke may remain viable for 14 days.^{15, 16} There is strong evidence for the presence of viable virus particles in electrocautery smoke over a range of diathermy settings.^{28, 29} HIV, *Human Papilloma virus*,³⁰ *mycobacteria* and *Hepatitis B* and *C* have all been demonstrated in particle size range 0.04-0.18µm and may all be carried⁸ and transmitted in the respirable aerosol.^{8, 27, 30}

Gene mutation: Previous studies of electrocautery during reduction mammoplasty have shown the smoke produced to be mutagenic.^{7, 31} However, the organic compound that could be responsible has not been identified. Of interest and concern is that, benzene, a known carcinogen has been identified in significant quantities in electrocautery smoke.⁷ This may be thought to be contributory as the mutagenic effect of electrocautery smoke may not be due to a single chemical agent.

Transfer and spread of tumour cells in the patient: More recently, accumulated evidences have shown that viable tumour cells are present in the electrocautery smoke.^{7, 28} These are contained in the aerosol which can be transferred, spread and settled over operating field previously not containing tumour cells, therefore, the risk of upstaging a tumour in a patient with malignant condition is theoretically present.

Table II: Hazards of diathermy to the patient, surgeon and operating team and theatre staff

<p>Patient</p> <ul style="list-style-type: none"> Burns injury Explosion Channeling effect Wound infection Poor wound healing Secondary haemorrhage Perforation of hollow viscus Electrocution Arrhythmias Transmission of infection Transfer and spread of tumour cell Gene mutation
<p>Operating team</p> <ul style="list-style-type: none"> Explosion Eye irritation Acute airway inflammation Hypoxic stress Transmission of infection Gene mutation
<p>Theatre staff</p> <ul style="list-style-type: none"> Explosion Eye irritation Electrocution Gene mutation

PREVENTION AND CONTROL OF HAZARDS

Surgical diathermy machine should be properly connected^{5, 6, 15} with the indifferent electrode properly placed and adequate contact ensured particularly if unipolar diathermy is intended to be used.

Its function should be tested before application during operation.^{5, 6}

The surgeon should be the only person to activate and control the diathermy and the active electrode often placed in a quiver when not in use.^{3, 5, 6, 15}

Surgical diathermy should never be used until "prep" solution has had time to evaporate and any pool such as in the umbilicus or in the vagina must be thoroughly mopped up^{5, 6}.

Flammable gases should not be used in patients where diathermy is intended to be used and the old habit of consulting the anaesthetist before switching the diathermy machine should not be discarded.^{5, 6}

Infusion of carbon dioxide through a scope during gastrointestinal endoscopy has been shown to discourage combustion.

Avoidance of mannitol and oral antibiotics during bowel preparation if diathermy is intended to be used for the patient should be borne in mind.

Use of diathermy should be avoided in operations that will involve the body appendages/end organs and if it must be used the adequate and proper contact with the rest of the body during surgery will go a long way to prevent channeling effect.^{5,20,21}

Large vessels should be ligated and patients with cardiac pace makers should be seen and reviewed by the cardiologists.^{5,6} Also, use of unipolar diathermy should be avoided in these patients as much as possible.

Theatre scavenging system: Operating room scavenging system if properly designed is meant to filter and evacuate aerosol and air contaminants⁸ and introduce fresh air in a gentle laminar flow pattern. Where this is not very effective, air contaminants and other aerosols would abound in the theatre and therefore increase the risk of inhaling them.

Use of face mask: The protection obtained by wearing of facial masks only concerns large particles. The American conference of government hygienists, international standard organization, the comite¹ Euro peer de normalization, have defined respirable aerosol as containing particles of 4.5um or smaller.⁷ Hence, airborne particles may not be effectively filtered by facial mask.⁷

Use of suction device: Simply holding a suction device close to the diathermy probe,⁸ have been shown to reduce significantly the amount of smoke that the patient, the surgeon and the operating team are exposed to. However, this is not a satisfactory long term solution as it requires an experienced assistant so that the surgeons' view is not impeded.

Government policy: The need to enforce government policy where they exist and to enact laws where they don't exist, on the control of airborne contaminants especially during surgical procedures can not be over emphasized. Issues like this have been addressed in many countries. For instance, in 1994 the Australian standard addressing the issue of airborne contaminant in workplace was published (and updated 1998) outlining the need to confine and contain contaminants generated by diathermy during surgical procedures.⁷ In UK, the updated control of substances hazardous to health (COSHH) regulation⁷ came into force in November 2002. All these and many other recommended efforts should be directed towards the controlled removal of surgical plume

Use of diathermy plume extraction system: The use of diathermy plume extraction system like the lina grey sharkTM, EMT Health care and clearflowTM have resulted in significant reduction of smoke reaching the surgeon's mask.⁸ ClearflowTM particularly have been noted to clear more than 99.9% particles down to 0.02um thus ensuring that hazardous products are not carried into the environment⁸. It is easy to set up, simple to operate and the pencil thickness was the same as that of a standard instrument making it comfortable in the hands. Clearing the plume improves vision in the operative field and noticeable reduction in the characteristic diathermy smell.⁸

CONCLUSION

Potential risk to the patient, surgeon and the operating team of continuous exposure to electrocautery appliances have been documented.^{5,8} It should be emphasized that estimated level of exposure of the patient, surgeon and the operating team in the course of the surgical procedure have not been determined. Optimizing health and safety in work place should be an ongoing goal^{3,5,6} in most institutions. Nevertheless, in view of the importance and the wide spread use of electrocautery, further studies would appear to be necessary to determine the extent of exposure of all operating room personnel and if necessary, to develop and enhance methods to reduce risk to health.

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